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5.8.7 Biomass Energy Systems

Using biomass as an energy source goes back thousands of years; it was our principal energy source until the 1800s. Biomass is organic matter, such as wood, agricultural crops, and animal waste. In essence, biomass is a form of stored solar energy—produced when plants use energy from the sun to convert air and carbon dioxide into plant tissue through photosynthesis. Energy can be derived from biomass by burning it directly, by converting it into energy-rich gases (gasification) that can fuel advanced gas turbines or fuel cells, and by converting it into liquid fuels (biofuels) that can fuel vehicles and other power-supply equipment. Using combined heat-and-power (cogeneration) systems and the most advanced biomass power-generation equipment, we could achieve total efficiencies of more than 80%.

From an environmental standpoint, biomass energy systems are attractive for several reasons:

- Biomass combustion is climate-neutral, since growing new biomass removes as much (or more) carbon dioxide from the atmosphere as the burning of it releases into the atmosphere.
- The production of certain biomass fuels can reduce pollution risks—for example, the capture of landfill gas (mostly methane) that would contribute to global climate change and the conversion of livestock waste into methane.
- Mixing biomass with coal in coal-fired power plants (co-firing) can reduce polluting emissions.
- Growing perennial biomass fuels instead of cultivated agricultural crops on steep, erosion-prone soils and on buffer strips along waterways can prevent siltation of surface waters and help to prevent runoff of agricultural chemicals and fertilizers.

Opportunities

Biomass energy systems should be considered for facilities with on-site electricity generation, especially when the waste heat from that power generation can be used for industrial processes or district heating (combined heat and power). Biomass energy is most feasible when there is an on-site (or nearby) source, such as waste wood from furniture manufacturing, agricultural crop residues, or a landfill with recoverable methane. Federal facilities can also support biomass energy use through green power purchasing programs in which biomass comprises part of the utility company's power generation mix.

Technical Information

Biomass can be used as an energy source in a number of different ways. These are as follows:

Co-firing: Adding a small percentage of biomass to the fuel supply of a coal-fired power plant—referred to as co-firing—is the easiest short-term option for increasing our use of biomass in power production. Co-firing up to 15% of the fuel mix is currently being done in six U.S. power plants, mostly using wood residues. One coal power plant demonstrated co-firing at 40% biomass substitution for coal. Through co-firing in the nation's coal-fired power plants, which have a combined capacity of 310 gigawatts (GW), biomass could supply 20 to 30 GW by the year 2020, according to the DOE BioPower Program.

Direct combustion of biomass is already widely practiced in certain industries, including lumber mills, furniture and millwork factories, and sugar mills (which produce bagasse as a by-product). In a direct-combustion facility, the biomass is typically burned in a large boiler, producing steam that drives a Rankine-cycle generator. This is much the same process used in coal-fired power plants, though the fuel-handling equipment is different. Most direct-combustion power plants are small (less than 25 MW) and operate at efficiencies of about 20%.

Gasification: Rather than simply burning biomass, a more efficient and cleaner way to extract heat energy from it is through gasification. In this process, biomass is heated in an oxygen-starved environment, which breaks down the biomass into its chemical constitu-

NREL worked with state, community, business, and utility partners to assist in the development of the 50-MW McNeil Generating Station in Burlington, Vermont, which uses wood fuel to produce electricity (cooling towers and excess steam are shown here). Photo: Dave Parsons

ents and produces *biogas*. This biogas can then be used as fuel in a high-efficiency gas turbine. Sophisticated *gasification combined cycle* (GCC) systems include a gas-turbine topping cycle and a steam-turbine bottoming cycle to achieve efficiencies nearly double those of direct combustion (37% vs. 20%).

Anaerobic digestion: Another way to produce energy from biomass is to anaerobically digest organic matter to generate methane, which can then be burned as fuel. Anaerobic (meaning oxygen-starved) digesters can be used to produce methane from municipal sewage treatment plants, livestock manure tanks, and other nutrient-rich organic matter. In Gronigen, Holland, a biomass digester system has recently been installed that digests the organic component of municipal solid waste to generate 2.5 MW of electricity.

Biofuels: The final approach described for converting biomass into usable energy is to produce liquid fuel from organic matter. Biofuels, as defined by the DOE Biofuels Program, are alcohols, ethers, esters, and other chemicals made from cellulosic biomass. While biofuels can be burned to generate electricity, most of the focus is on biofuels for transportation, especially ethanol and biodiesel. More than 1.5 billion gallons (5.7 billion liters) of ethanol—derived from biomass through a fermentation process—are added to gasoline each year to improve vehicle performance and reduce air pollution. Alcohol is typically used in a 10% blend with gasoline. Biodiesel is an ester that can be made from a variety of vegetable oils and animal fats. Roughly 30 million gallons (113.5 million liters) of U.S. biodiesel are produced annually; most of that is used in a 20% blend with conventional diesel fuel.

References

Numerous documents are available on the BioPower and Biofuels Web sites listed below.

Contacts

Biomass Power Program, National Renewable Energy Laboratory, Golden, CO; www.eren.doe.gov/biopower/.

National Biofuels Program, National Renewable Energy Laboratory, Golden, CO; www.biofuels.nrel.gov.